# Mars Pathfinder Atmospheric Entry Reconstruction

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## Extended Abstract

## INTRODUCTION

Five minutes after entering the Martian atmosphere, the Mars Pathfinder spacecraft impacted the surface of the planet, and bounced and rolled to a stop. This paper presents the results of an effort to reconstruct the Pathfinder atmospheric entry trajectory, and assess the performance of the Entry, Descent and Landing (EDL) system. In addition, a reconstruction of the Mars atmosphere profile encountered by the Pathfinder entry vehicle will be presented.

## ENTRY, DESCENT AND LANDING SEQUENCE OF EVENTS

The Pathfinder spacecraft entered Martian atmosphere directly from the Earth-to-Mars interplanetary transfer trajectory, with an inertial velocity of 7.35 km/s[1]. The Pathfinder EDL sequence of events is shown in Fig. 1. Thirty minutes prior to atmospheric entry, the cruise stage was jettisoned. The entry vehicle reached maximum stagnation point heating and peak dynamic pressure during the initial 70 s of the entry phase. At 170 s past entry, a parachute was deployed, followed by the release of the heatshield 20 s later. The lander was deployed below the backshell along a 20 m bridle. At an altitude of 1.6 km above ground level (AGL), the on-board radar altimeter acquired the ground. Altimeter data was used by the flight software to inflate an airbag system and fire a set of three solid rockets (mounted on the backshell) at an altitude of 98 m AGL. At an altitude of 22 m, the bridle was cut, and the lander fell directly to the surface, buffered at ground impact by the airbag system. Sufficient impulse remained in the solid rockets to carry the backshell and parachute to a safe distance away from the lander.

The Pathfinder target landing site is located at the outflow of a catastrophic flood system in the Ares Valles region at 19.32°N, 33.55°W, only 23 km from the center of the 200 km x 100 km target landing ellipse[2].

## TRAJECTORY RECONSTRUCTION

The Pathfinder entry trajectory has been reconstructed from several data sources. Radiometric tracking data taken during the interplanetary approach phase provides an estimate of the vehicle state at atmospheric entry. On-board accelerometer measurements taken during EDL provide a time-history of the entry vehicle body-fixed accelerations. Figure 2 shows the vehicle acceleration dynamics during and shortly following the parachute deployment event. Radar altimeter measurements during terminal descent are available for the final 1600 m of flight. Finally, one-way Doppler data has been constructed from the carrier signal transmitted by the spacecraft during atmospheric entry.

Trajectory reconstruction from atmospheric entry through landing has been accomplished through filtering accelerometer and altimeter data, along with the derived one-way Doppler data. The "best estimate" trajectory is estimated in a minimum variance sense, and is "smoothed" by integrating backwards in time to remove any discontinuities.

Vehicle attitude during the entry phase has been estimated, and it will be shown that two (and possibly a third) regions of static instability, predicted pre-flight[3], actually occurred.

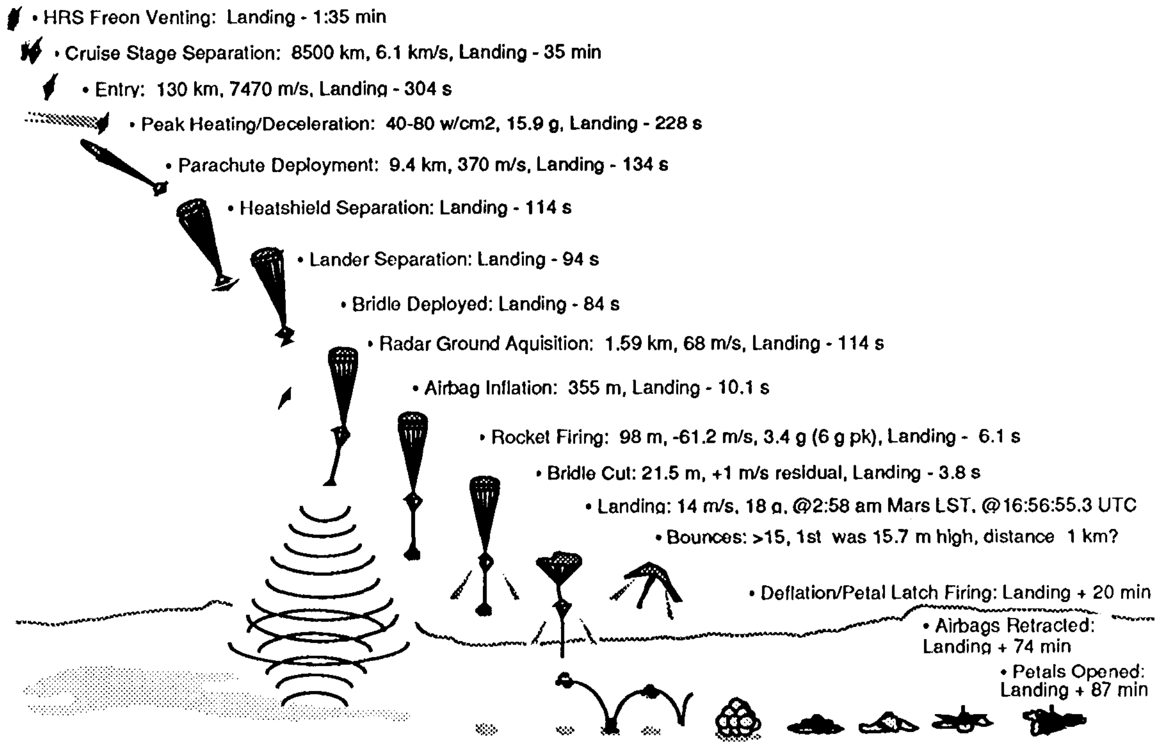


Figure 1. Mars Pathfinder EDL Sequence of Events

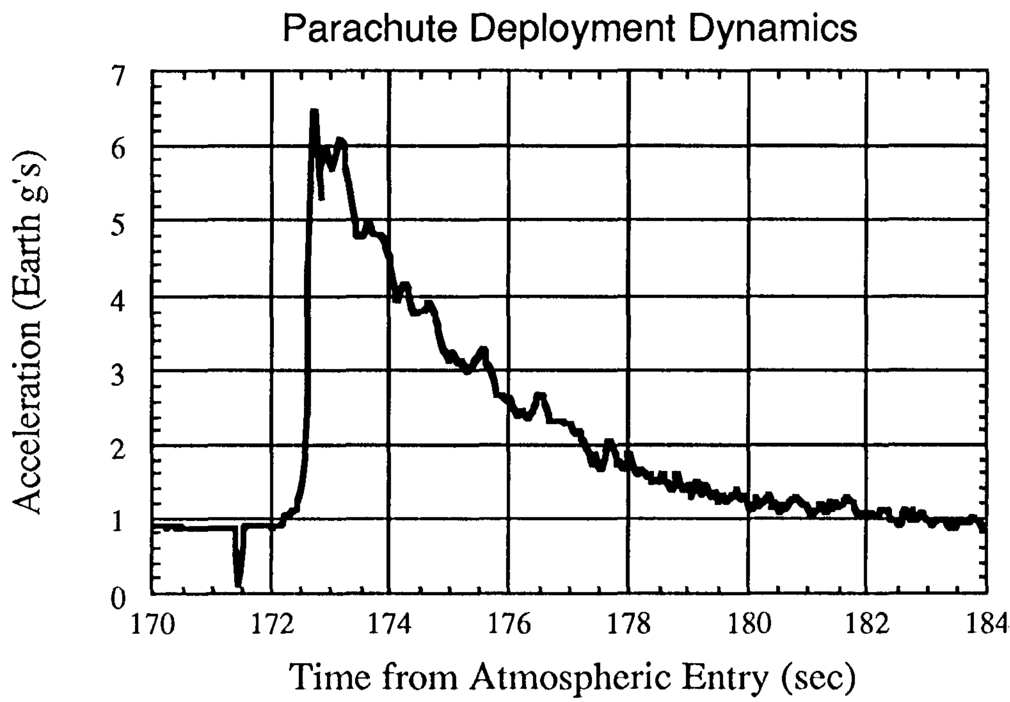


Figure 2. Parachute Deployment Acceleration History

## MARS ATMOSPHERE PROFILE

An "engineering" profile of the Mars atmosphere during the Pathfinder entry, in terms of temperature, pressure, and density, has been constructed. Two independent methods were employed in determining the atmosphere profile. From the vehicle acceleration as a function of time, the density was determined directly using a process similar to that discussed in Reference 4. In addition, an iterative approach was employed, varying the temperature profile from the ground up and using hydrostatics and the Ideal Gas Law to derive pressure and density. Taking the best estimate trajectory as "truth," the temperature profile is optimized to produce consistent simulated trajectories.

## ACKNOWLEDGEMENTS

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